Paper

FANET Drone's 4K Data Applications, Mobility Models and Wi-Fi IEEE802.11n Standards

Ghassan A. QasMarrogy

College of Engineering, Department of Communication and Computer Engineering, Cihan University-Erbil, Kurdistan Region, Iraq

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Abstract—With growing popularity of unmanned aerial vehicles (UAVs), the importance of flying ad-hoc networks (FANETs) is enhanced by such applications as 4K video recording, communications in search and rescue missions and goods deliveries, to name just a few. This, in turn, stimulates research on different topologies of networks existing between UAVs, with studies in this field being essential to improving performance of such networks. Several problems must be solved to effectively use UAVs in order to offer stable and reliable massive data transmission capabilities, taking into consideration quickly changing FANET topologies, types of routing, security issues, etc. In this paper, a comprehensive evaluation of FANETs used by UAVs is presented in terms of communication network challenges, data types, mobility models and standards applied in order to achieve best performance. The evaluation presented herein covers such areas as data throughput, retransmission attempts and delay.

Keywords—4K data transmission, FANET, mobility models, UAV.

1. Introduction

A flying ad-hoc network (FANET) is a combination of fast-flying devices (drones) and infrastructure-less ad hoc networks [1]. Due to a high degree of mobility that quickly changes the topology of the network, different types of highly dynamic technologies for 4K video recording and environment sensing [2] are used, as shown in Fig. 1. In consideration of the above, FANETs operate in challenging environments and rely on powerful equipment to ensure operational multi-tasking capability. Unfortunately, drones are characterized by very limited resources in terms of hardware and power supply, limited wireless radio range, throughput, as well as payload capacity [3], [4].

IEEE 802.11 constitutes a component of the IEEE 802 set of local area network (LAN) protocols and is concerned with media access control (MAC) and physical layer (PHY) solutions relied up to implement wireless local area networks (WLANs) in various frequency bands, including, but not limited to 2.4, 5, 6 and 60 GHz bands [5]. In this paper, the 802.11n standard is analyzed as it is the latest protocol that supports both 2.4 GHz and 5 GHz frequencies [6].

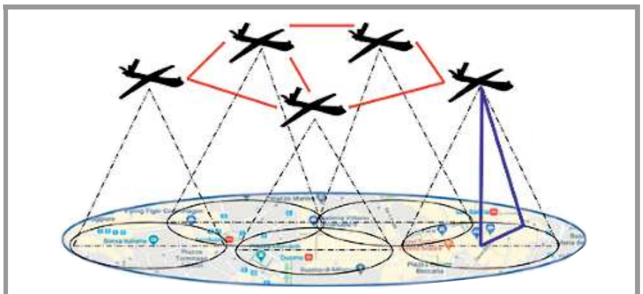

Fig. 1. FANET UAV communications scheme.

In this paper, an evaluation of FANET is presented, focusing on the communication network-related challenges, data types, mobility models and standards. The evaluation is concerned with throughput, retransmission attempts and delay requirements that need to be satisfied to achieve the best 4K video transmission parameters using FANET networks without any fixed infrastructure.

The paper is structured as follows. Section 2 presents the related work. Section 3 offers a brief description of the routing protocols, mobility models and IEEE 802.11n communication standards. Section 4 shows the results of the performance analysis. Finally, in Section 5, conclusions and the future work are presented.

2. Related Work

Many authors attempted to solve the most crucial problems affecting FANETs and tried to evaluate different types of technologies to ensure reliable data transmission and good performance.

In [7], a novel scheme was proposed in connection with the adaptive energy efficient hello-interval scheme (EE-Hello). It was based on best distance approximation that was harnessed to send hello messages and identified the number of UAVs required to achieve the task at hand. The proposed scheme saved up to 25% of energy needed. In [8], a new course-aware opportunistic routing (CORF) protocol was proposed for FANETs to calculate the best neighbor position in order to transfer data efficiently. In comparison with other routing protocols, the proposed solutions offered a significant performance gain, with better message delivery rates and shorter delays.

In [9], an attempt was made to enhance in IEEE 802.11n 5 GHz video streaming in terms of throughput, retransmission attempts and delay. The results show an improvement that is achieved in video streaming by using WNIC parameters of the UAV. In [10], different mobility models were compared and evaluated, such as random waypoint mobility (RWPM), pursue mobility model (PRS), semi-random circular movement (SCRM), and Manhattan grid mobility model (MGM). The results show that MGM exerts the greatest impact on the delay and packet dropping ratios. Paper [11] focuses on data distribution service (DDS) middleware and presents a logic analysis and an evaluation of competing DDS implementations, and thus could serve well as input for deciding which of these solutions is best suited for a given situation, with a practical performance evaluation performed based on several different scenarios to effectively compare the most frequent DDS implementations. The results show that higher delays are obtained when higher memory requirements are present.

3. FANET Parameters

There are different types of routing protocols that have been used and evaluated for FANET, but because of the 3D nature of UAVs, it is very difficult to test all these routing protocols simultaneously, under different mobility models and IEEE standards. In [12], the authors classified FANET routing protocols into different categories, such as proactive, reactive, and hybrid protocols (Fig. 2) [12]. Based on this taxonomy, in this paper, two main routing protocols were chosen as best suited for FANET: ad-hoc on-demand vector (AODV) and optimized link state routing protocol (OLSR).

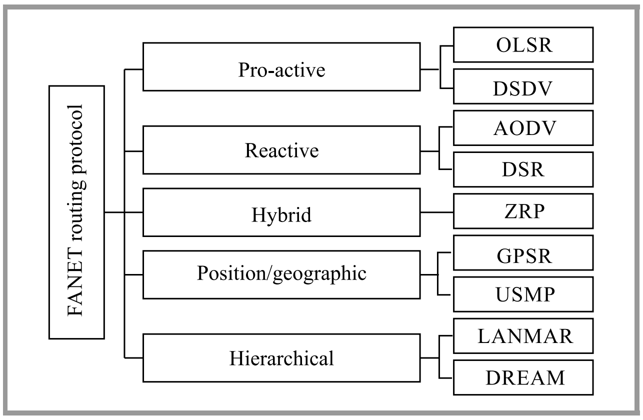

Fig. 2. FANET routing protocol.

Being a reactive type protocol, ad-hoc on-demand distance vector (AODV) uses sequence numbers and the broadcast discovery mechanism to calculate the best recent fresh route to the final node. The discovery phase starts when a node needs to transmit data packets to the destination node while recording all recent fresh routes in the node routing table until the transmission ends. Thereafter, the main routes will be deleted and the next phase of the path discovery process will commence when another transmission starts. This protocol causes more delay but has lower overhead during the transmission compared to other routing protocols [13].

The proactive optimized link state routing (OLSR) protocol uses multipoint relays (MPR), i.e. groups of selected devices, to exchange their recent information about fresh routes between the nodes, with such an approach offering shorter delays in the route discovery phase. The hello messages are broadcast between neighbor nodes, and the fresh routes are stored at frequent intervals, continuously, without any requests from other nodes. This protocol allows to shorten the delays. Its drawback consists in a higher overhead caused by large amounts of data transmitted to make the routes available all the time [13].

3.1. FANET Mobility Models

Due to the high degree of object mobility in FANETs, data may be dropped, delayed and not received at all [14]. Therefore, it is very important to evaluate the performance of a FANET network based on real-life scenarios. Many researchers use the random waypoint model (RWPM) to analyze and simulate FANET performance. Unfortunately, this model forces all UAVs to fly in random directions, which affects communication links between the nodes and degrades data transmission performance.

In this paper, three types of real mobility models are used and analyzed: RWPM, pathway mobility model (PMM) and semi-random circular movement (SRCM), as shown in Table 1 [14].

Table 1
Realistic mobility model scenarios

Mobility model	Scenarios	Realistic scenario description
RWPM	Search and rescue	A random search of target zones. Random area scanning.
PPM	Object tracking	Surveillance of city roads. Surveillance over a crash location until rescue services arrive
SRCM	Surveying, patrolling and object tracking	Surveillance of an object

The RWPM model uses different timing for UAV hover and movement scenarios. It calculates the direction and the speed of UAVs based on random values. When the transmission starts, the UAV waits, hovering, for a specific period of time, and then it starts moving to a preselected position at a random speed chosen from range uniformly prescribed for the entire simulation process. This procedure is repeated until the simulation is finished. Due to random variations in speed and directions, this approach corresponds to real-life scenarios, such as search and rescue missions or wireless sensor networks covering extensive areas [15].
The SRCM model uses hexagon shaped routes instead of random tracks with a specified speed value. The UAV is moving within area defined with a specified hexagon. This model may be used in real life conditions for surveying, patrolling and target tracking [16].
The PMM model uses a straight route preference. It specifies the first and the last point between which the UAV moves at a fixed speed. After reaching the last point a new destination will be selected with a new speed and direction, and this procedure will be repeated until the simulation is finished. Such a model is suitable for target tracking, thermal monitoring, as well as for video recording and transmission [17].
Incorporating IEEE 802.11n-based Wi-Fi connectivity relying on 2.4 GHz and 5 GHz bands may decrease interference and delays while simultaneously increasing the speed of data transmission, as shown in Fig. 3 [18].

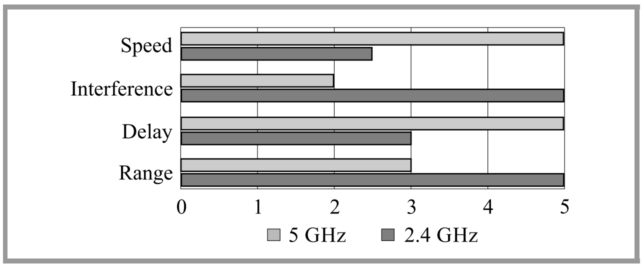

Fig. 3. Dual band IEEE 802.11n feature comparison.

The 5 GHz band offers higher speeds, and is therefore capable of improving performance and throughput of FANETs. The 5 GHz band also supports a higher number of network connections and communication channels than its 2.4 GHz counterpart – a property that is essential for providing 4K video streaming [19]. The shorter range of 5 GHz may be enhanced significantly by increasing the size of the directional antenna [20].

4. Simulations and Results

Three routing protocols were analyzed using the NS3 simulator. Three realistic mobility models and two types of IEEE 802.11n standards have been taken into consideration to evaluate such metrics as throughput, delay and retransmission attempts.

4K video streaming was chosen to simulate high data traffic rates.
A 60-second 4K video stream (3840 $\times$ 2160) at 30 fps and with 24 bit color means that 427 MB of data need to be transmitted. Other simulation parameters are summarized in Table 2.

Table 2
Simulation environment parameters

Parameters	Values
Area size	1500 $\times$ 1500 m
Number of nodes	40 UAVs
Routing protocols used	AODV, OLSR
Traffic type	4K video streaming
Mobility models	RWPM, PMM, SRCM
Node speed, altitude	20 m/s, 20 m
Simulation time	600 s
IEEE 802.11n standards	2.4, 5 GHz

Figure 4 shows the throughput of FANET for IEEE 802.11n in 2.4 and 5 GHz bands. AODV offers better results in 5 GHz than in 2.4 GHz, while OLSR maintains the same performance, because AODV needs more bandwidth to keep its fresh routes updated and to broadcast control packets all the time. 4K video streaming requires more bandwidth to support large packet transmissions.
The activity of SRCM is limited or non-existent due to the rounded movement of UAVs, resulting in high distances between them (and the range of 5 GHz is shorter than in the case of 2.4 GHz). PMM turns out to be the best mobility model for all types of transmissions and standards. This is because PMM is capable of establishing a direct communication path and of maintaining fresh routes for longer periods than in the case of RWPM.

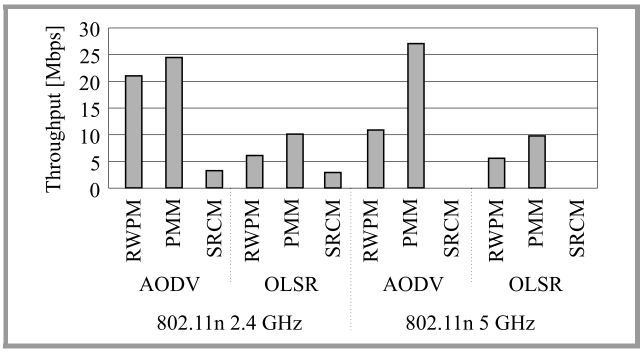

Fig. 4. Data throughput for IEEE 802.11n, mobility models, and routing protocols.

Simulation results shown in Fig. 5 confirm that delays experienced in FANETs are higher when using 2.4 GHz, as 5 GHz relies on higher bandwidth. The results achieved with the use of the PMM mobility model are better in all scenarios, as it continuously establishes a direct path to the packets. OLSR results remain the same, as in this approach fresh routes are broadcast regularly by control packets.

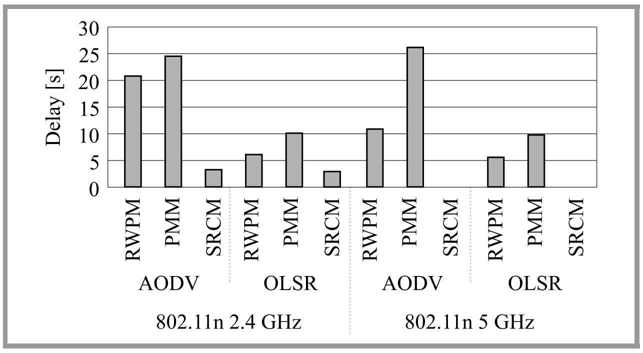

Fig. 5. Delay for both versions of IEEE 802.11n, mobility models, and routing protocols.

The simulation results presented in Fig. 6 show that the number of retransmission attempts undertaken by FANET is higher for 5 GHz, as the range of this band is shorter, which may result in a greater number of route breaks that increase the number of retransmission attempts. AODV renders also better results than OLSR in 5 GHz for the PMM mobility model, resulting in a breakthrough discovery that AODV outperforms OLSR. Better results obtained in 5 GHz may be solved easily by changing the mobility model to a more preferable scenario that makes all UAVs move closer to each other in order to decrease delay and increase network transmission throughput.

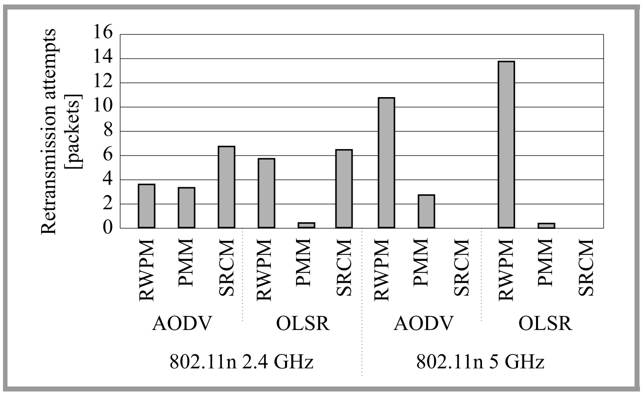

Fig. 6. Retransmission attempts for IEEE 802.11n, mobility models, and routing protocols.

5. Conclusion

Simulation results indicate the throughput increases when 5 GHz is used along with PMM mobility models and AODV, while OLSR remains stable in all tested scenarios. AODV is also capable of rendering better performance with shorter delays, as it utilizes the entire capacity of the bandwidth, while 5 GHz suffers from more route breakages during transmission, as its range is shorter than that of the 2.4 GHz band.

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Ghassan A. QasMarrogy received his B.Sc. Degree in Computer and Communication Engineering in 2009, and M.Sc. Degree in Electrical and Electronic Engineering from Eastern Mediterranean University in 2013. He is currently working as a lecturer at the Department of Computer and Communication Engineering. His research interests include data and multimedia communication, wireless and ad-hoc networks, MANET and FANET networks, as well as security and cybersecurity in communication.

E-mail: Ghassan.qasmarrogy@cihanuniversity.edu.iq
College of Engineering
Department of Communication and Computer Engineering
Cihan University-Erbil
Kurdistan Region, Iraq